



# **Man-made fibres and Sustainability**

**Source:  
New Cloth Market**

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Man-made fibres are classified into three classes, those made from natural polymers, those made from synthetic polymers and those made from inorganic materials.

## Fibres from Natural Polymers

The most common natural polymer fibre is viscose, which is made from the polymer cellulose obtained mostly from farmed trees. Other cellulose-based fibres are Lyocell, Modal, Acetate and Triacetate. Less common natural polymer fibres are made from rubber, alginic acid and regenerated protein.

## Fibres from Synthetic Polymers

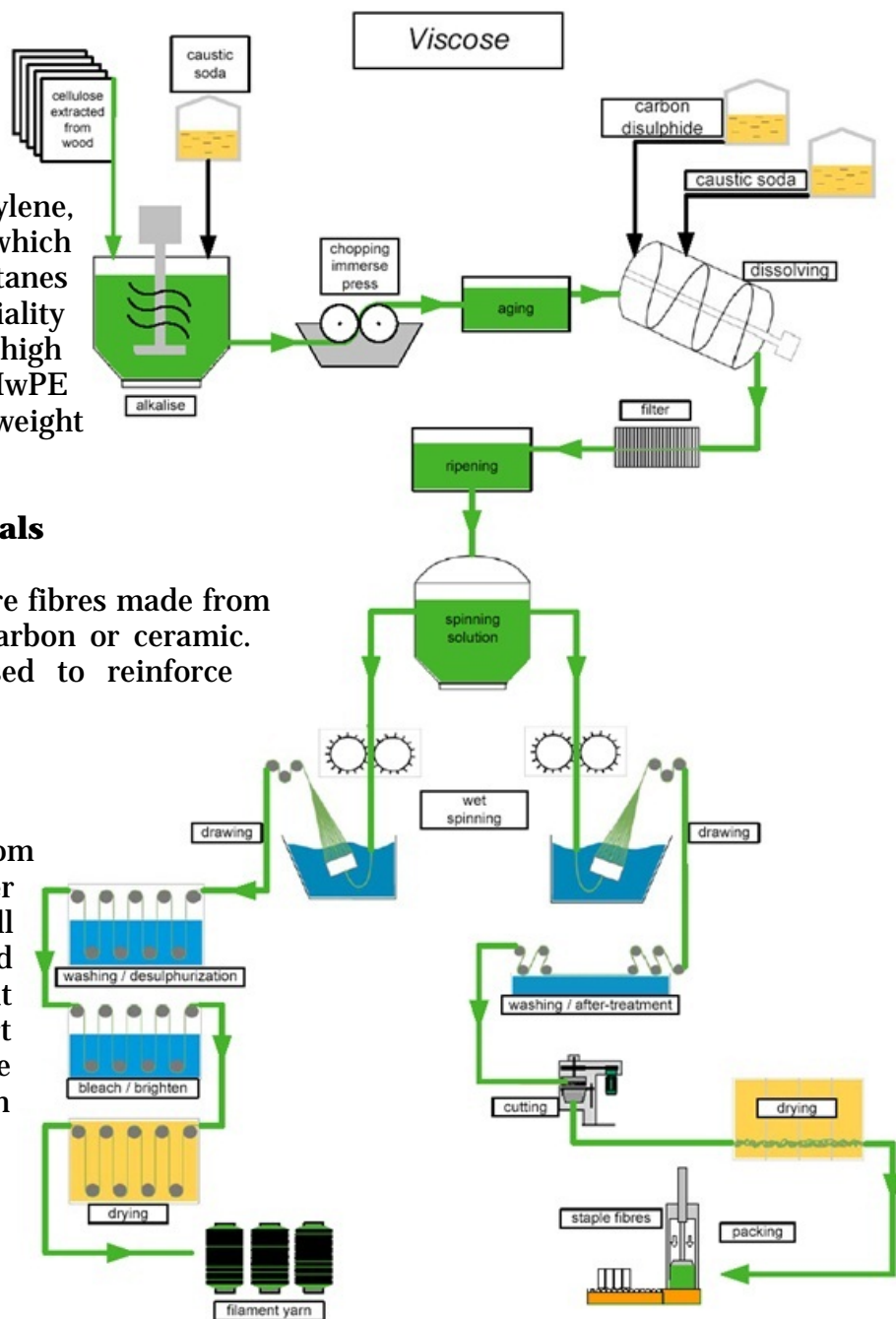
There are very many synthetic fibres i.e. organic fibres based on petrochemicals. The most common are polyester, polyamide (often called nylon), acrylic and modacrylic, polypropylene, the segmented polyurethanes which are elastic fibres known as elastanes (or spandex in the USA), and speciality high-tenacity fibres such as the high performance aramids and UHMwPE (Ultra High Molecular weight PolyEthylene).

## Fibres from Inorganic Materials

The inorganic man-made fibres are fibres made from materials such as glass, metal, carbon or ceramic. These fibres are very often used to reinforce plastics to form composites.

## Viscose

There are several fibres made from the naturally occurring polymer cellulose, which is present in all plants. Mostly cellulose from wood is used to produce the fibres but sometimes cellulose from short cotton fibres, called linters, is the source. By far the most common cellulosic fibre is viscose fibre.



Viscose is defined by BISFA as being "a cellulose fibre obtained by the viscose process". It is known as rayon fibre in the USA. Although several cellulosic fibres had been made experimentally during the 19th century, it was not until 1905 that what has become the most popular cellulosic fibre, viscose, was produced.

## **Production**

Viscose fibres are made from cellulose from wood pulp. The cellulose is ground up and reacted with caustic soda. After an ageing waiting period, the ripening process during which depolymerisation occurs, carbon disulphide is added. This forms a yellow crumb known as cellulose xanthate, which is easily dissolved in more caustic soda to give a viscous yellow solution. This solution is pumped through a spinneret, which may contain thousands of holes, into a dilute sulphuric acid bath where the cellulose is regenerated as fine filaments as the xanthate decomposes.

## **Properties and End-Uses**

Viscose fibres, like cotton, have a high moisture regain. It dyes easily, it does not shrink when heated, and it is biodegradable. It is used in many apparel end-uses, often blended with other fibres, and in hygienic disposables where its high absorbency is of great advantage. In filament yarn form it is excellent material for linings. It is used very little in home furnishing fabrics but in the industrial field, because of its thermal stability, a high modulus version is still the main product used in Europe to reinforce high speed tyres.

## **Modal**



Modal Fibres belong to the second generation of viscose fibres and are high wet modulus fibres made by a modified viscose process with a higher degree of polymerisation and modified precipitating baths. This leads to fibres with improved properties such as better wear, higher dry and wet strengths and better dimensional stability.

Modal fibres are smooth and soft, making it very suitable for body conscious clothing, like intimate apparel.

Modal fibres are highly absorbent and quickly soak up water so that it still feels dry even when holding a considerable amount of water.

## **Acetate**

### **Acetate and triacetate**

The term acetate fibre is used to describe fibres made from cellulose acetate. The difference between acetate and triacetate fibres lies in the number of the cellulose hydroxyl groups that are acetylated. For acetate fibres the number lies between 75% and 92%, for triacetate fibres it is more than 92%.

## **Production**

Wood cellulose is swollen by acetic acid and then converted to cellulose acetate using acetic anhydride and it is then dissolved in acetone. The resulting viscous solution is

pumped through spinnerets into warm air to form filaments. The acetone evaporates and is recovered. The filaments are then wound up as filament yarns or collected as a tow.

## **Properties and End-Uses**

These fibres are different from viscose in that they are thermoplastic. They are generally dyed using disperse dyes, absorb little water and can be textured. Although the dry strength of the two types are similar, triacetate has a higher wet strength. It also has a high melting point, 300 degrees C, compared with 250 degrees C for diacetate. Main end-uses for the filament yarns are linings and dresswear. There is very little staple fibre made from these fibres but acetate tow is the major product used for cigarette filters.

## **UHMwPE**

UHMwPE stands for Ultra High Molecular weight PolyEthylene. This fibre was invented more than 20 years ago and is in production since 1990.

## **Production**

The fibre is manufactured by means of a gel-spinning process that combines extreme high strength with incredible softness.

## **Properties and end-uses**

The fibre is 15 times stronger than steel on a weight-for-weight basis. Also this PE has a very low specific gravity and is ideal for lightweight solutions. It is chemical resistant, UV resistant and moisture resistant.

It is used in aviation, fishing industry, ropes, medical applications, protective gloves and life protection applications (armour protection).

## **Lyocell**

A new generation of cellulosic appeared in the market in December 1992 when a commercial plant in the USA started to make a lyocell staple fibre, based largely on European man-made fibre industry research. Subsequently, two European production plants have opened.

## **Production**

The process used to make lyocell fibres is a solvent spinning process. The cellulose is directly dissolved in the solvent N-methylmorpholine n-oxide (NMMO) containing just the right amount of water. The solution is then filtered and spun through spinnerets to make the filaments, which are spun into water. The NMMO solvent is recovered from this aqueous solution and reused.



## Properties and End-Uses

The lyocell fibres, like other cellulosics, are moisture absorbent and biodegradable. They have a dry strength higher than other cellulosics and approaching that of polyester. They also retain 85% of their strength when wet. Under certain conditions lyocell fibres fibrillate which enables fabrics to be developed with interesting aesthetics. Non-fibrillating versions are also available. Lyocell fibres are mostly used for apparel fabrics, especially outerwear, but it has been shown that, due to the fibrillating property some very interesting nonwoven fabrics can be made as well.

## Acrylic

### Acrylic and Modacrylic

BISFA defines acrylic fibres as "fibres composed of linear macromolecules having in the chain at least 85% (by mass) of acrylonitrile repeating units". Modacrylic fibres have, in the chain, at least 50% and less than 85% by mass of acrylonitrile. The first commercial fibres were introduced in the USA and Germany in 1948.

## Production

The starting materials for acrylonitrile are propylene and ammonia, which are reacted with oxygen in the presence of catalysts. The acrylonitrile is then polymerised to produce polyacrylonitrile (PAN). The PAN is then spun into fibres from a solution in a solvent. Two process routes are used, wet spinning in which the fibres are spun into an aqueous coagulation bath and dry spinning in which the fibres are spun into hot air.

The fibres are then stretched, washed and crimped. The modacrylic fibres contain halogen comonomers such as vinyl chloride or vinylidene chloride, and have flame-retardant properties.

## Properties and End-Uses

Acrylic fibres are soft, flexible and have a high loft. For this reason they are widely used in knitted apparel end-uses such as sweaters and socks. In addition to knitted apparel, home furnishing and blankets are other important applications due to its excellent heat retention.

## Polyamide

A polyamide fibre is defined by BISFA as being "a fibre composed of linear macromolecules having in the chain recurring amide linkages, at least 85% of which are joined to aliphatic or cycloaliphatic units". There are many polyamide fibres made but only two, described below, are made in significant



quantities. The first fibres made from polyamide polymers were produced in 1938 in the USA and Germany. In the USA the raw materials, which were used to produce the polymer, were adipic acid and hexamethylene diamine. Since both chemicals contain 6 carbon atoms the new polymer was named polyamide 6.6. In Germany caprolactam was polymerised to produce a different fibre known as polyamide 6.

### **Production**

To produce fibres from the polyamide polymers the molten polymer is pumped through spinneret holes at a temperature approaching 300 degrees C to form filaments that are cooled and solidified in a quench air stream. If filament yarn is being produced the filaments are then oiled and wound onto bobbins.

If staple fibres are being produced, very many filaments are bundled together to form a tow which is subsequently stretched, crimped and cut to the desired length.

### **Properties and End-Uses**

In weaving the main end-use is for outerwear and technical fabrics like airbags and cappel for tyres. In knitting, stockings, hosiery, tights and outerwear are important outlets. Carpets and ropes are also important sectors.

### **Polyester**

A polyester, according to BISFA, is "a fibre composed of linear macromolecules having a chain at least 85% by mass of a diol and terephthalic acid". The first polyester was made in the UK in 1941. This polyester, known as polyethylene terephthalate (PET) has become by far the world's major man-made fibre. Other polyesters such as polybutylene terephthalate (PBT) and polytrimethylene terephthalate (PTT) are made but in much smaller quantities.

### **Production**

Polyester fibres are made in a very similar way to polyamide. Some plants take polyester polymer chips and melt them, at around 280 degrees C and then extrude the melt into continuous filaments to be wound onto packages or collected in cans as a tow before being stretched, crimped and cut into staple fibre. Other plants produce the polymer by a continuous process (CP) and form it into fibres without producing chips. A growing quantity is made by recycling PET bottles and other waste. If fully oriented yarns (FOY) are being produced the fibres are drawn on the spinning machine. If the yarn is to be textured, partially oriented yarns (POY) are spun.

### **Properties and End-Uses**

Globally, polyester is by far the greatest man-made fibre. It is the workhorse for many, many applications because of its generally good properties at the lowest price. Apparel accounts for a large share of usage of polyester fibres or as blends. Industrial use, such as tyre cord fabrics, and unspun uses such as furniture fillings and nonwovens, are both expanding rapidly.

### **Polyolefins**

There are two polyolefin polymers used to make synthetic fibres, polypropylene and polyethylene, with polypropylene being by far the most important. The BISFA definition for polyethylene fibres is "fibre composed of linear macromolecules of unsubstituted saturated aliphatic hydrocarbons" and for polypropylene fibres "fibre composed of linear macromolecules made up of saturated aliphatic carbon units in which one carbon atom in two carries a methyl side group...". Polyethylene was first produced in the UK in 1933 by polymerising ethylene under pressure. In 1938 in Germany polyethylene was made by polymerising ethylene in an emulsion. Polypropylene was commercialised in 1956 by polymerising propylene using catalysts. Both of these polyolefins are very important in plastic moulding and for making plastic sheet but both are also spun into synthetic fibres on a large scale.

## **Production**

Polyolefin fibres are made by melt spinning. Usually polymer granules - made by specialist producers rather than fibre companies - are fed to an extruder which melts the polymer which is then pumped through a spinneret. The filaments are cooled in an air stream before being wound on a package or collected in cans as a tow. Because the fibres are difficult to dye, coloured pigments are often added to the polymer stream before extrusion. An alternative process is to produce a film, cut the film into strips and then fibrillate the individual strips before winding onto a package. A new family of catalysts to make polypropylene has been developed called metallocene catalysts. It is claimed that the polymers made from these catalysts can be spun to finer counts and drawn to give higher tenacities than existing polymers.

## **Properties and End-Uses**

Both polyolefin fibres have a density less than 1.0 and therefore, at a given decitex, are thicker than other man-made fibres and give more cover. They do not absorb moisture, which is an advantage in many end-uses, but without modification, they cannot be dyed. Their melting points are around 130 degrees C for polyethylene and 160 degrees C for polypropylene. They have a high resistance to chemical attack and modern polypropylene fibres have a high resistance to UV degradation.

Polypropylene fibre consumption has grown rapidly during the past decade. This is due largely to its acceptance as a carpet fibre and the growth in the nonwoven end-uses, especially disposables and geotextiles where polypropylene is now the dominant fibre.

In addition to these products the properties of the polyolefins make them ideal for end uses such as ropes, tapes, twines, fishing nets and FIBCs.

## **Aramid**

Aramid is a contraction of aromatic and polyamide. BISFA defines these fibres as "fibre composed of linear macromolecules made up of aromatic groups joined by amide or imide linkages". There are two types of aramid: the meta-aramids and the para-aramids.

## **Production**

The polymer poly-metaphenylene isophthalamide is used to make meta-aramids and the polymer p-phenylene terephthalamide to make para-aramids. Because the aramids decompose before they melt they are produced by wet and dry spinning methods.

Sulphuric acid is the normal solvent used in the spinning processes. In wet spinning a strong solution of the polymer, which also contains inorganic salts, is spun through a spinneret into weak acid or water. In this bath the salts leach out. In the dry spinning process the salts are more difficult to remove and this process is only used to produce the weaker meta-aramid fibres. In both processes post treatment of the fibres by additional drawing is used to optimise fibre properties. Aramid products are available as filament yarn, staple fibre or pulp.

### **Properties and End-Uses**

The p-aramid fibres have a very high strength, 5 times stronger than steel, little loss of strength during repeated abrasion, flexing and stretching. It has an excellent dimensional stability. The m-aramid fibres are used for their excellent heat resistance. Some of the main end-uses for meta-aramids are protective clothing, hot gas filtration and electrical insulation. Para-aramids are used to replace asbestos in brake and clutch linings, as tyre reinforcement, and in composites such as materials for aircraft, boats, high-performance cars and sports equipment. Members of police forces and armed forces wear anti-ballistic aramid apparel.

### **Elastane**



Elastane yarns are characterised by their ability to recover from stretch. BISFA describes them as "a fibre composed of at least 85% by mass of a segmented polyurethane which, if stretched to three times its unstretched length, rapidly reverts substantially to the unstretched length when the tension is removed". Although elastane was first synthesised in 1937, it was not commercialised as a fibre until 1958.

### **Properties and End-Uses**

In addition to their remarkable stretch and recovery properties, elastanes resist perspiration and cosmetic oils, are easily washable, are dyeable and have moderate abrasion resistance. Elastane yarns are often covered with another fibre. This provides more bulk and improves abrasion resistance. The main end-uses for the yarns are garments and other products, where comfort and/or fit are important. Typical examples are sports and leisure wear, swimwear, elastic corset fabrics and stockings.

### **Glass**

There are many inorganic fibres, including glass, carbon, metal and ceramic. They are used particularly in the industrial fibre sector. Glass is the most important inorganic fibre.

### **Production**

It is produced by melting glass pellets in an electric furnace at around 1500 degrees C. The molten glass passes through small holes in a plate at the base of the furnace. After cooling in air it is wound up on a package. Alternatively it can be spun centrifugally to form a web.

### **Properties and End-Uses**



There are several types of glass fibre produced. They have in common high moduli, high rot resistance, low moisture uptake, are brittle and have low breaking extensions. Glass is used extensively for insulation in the form of a felt and also for reinforcing plastics to make boats, caravans, automobile parts etc. Other lesser uses are flame-resistant curtains and décor fabrics.

### Carbon

The BISFA definition of a carbon fibre is "fibre containing at least 90% by mass of carbon obtained by thermal carbonisation of organic fibre precursors".

### Production

The common precursors used to make carbon fibres are specifically made polyacrylonitrile(PAN) and pitch. If pitch is used the process consists of extrusion, oxidation and graphitisation. If PAN is used, a tow is oxidised, then carbonised followed by graphitisation.



World Production of Cotton, Wool & Man-made Fibres			
Year	1990	2000	2010
Raw Cotton	48%	35%	31%
Raw Wool	5%	3%	1%
ManMade Fibres	47%	62%	68%

### Properties and End-Uses

Carbon fibres are characterised by having high moduli and high strength, especially when embedded in a matrix such as epoxy resin. They are also brittle and have a low density. The main end-uses are as reinforcement fibres in composites for the aircraft and aerospace industries and sports goods.



### Man Made Fibres – Sustainability Elements

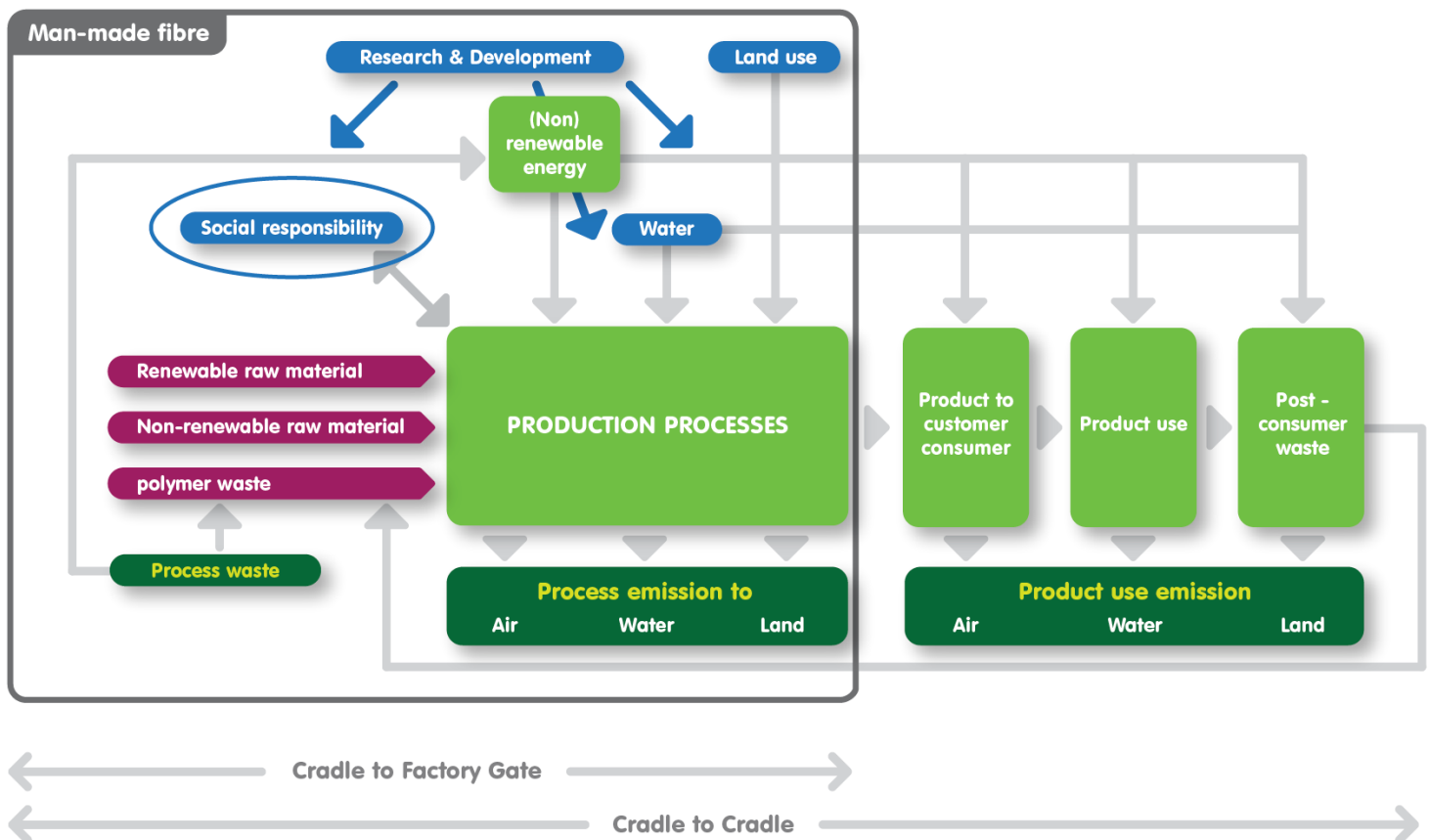
The increasing importance of sustainability, as the concept for doing business worldwide, and supports the commitment of its members to deliver a sustainable product.

Its member companies throughout Europe are consistently committed to minimising the environmental impact of their products and processes by:

- maximising efficiencies in the use of resources (raw materials, energy and water),
- continuous reduction of waste, and optimal utilisation of unavoidable waste,
- further reducing emissions,
- being innovative and by the development of products and applications with an enhanced sustainability profile,
- respecting and going beyond the European high standards of work safety and social conduct.

Industry in general and the Man-made Fibres (MMF) Industry in particular, have a long history in the pursual of initiatives which support sustainability. Since 1992, the responsible care programme has been adopted in many countries, and has been applied by man-made fibre producers.

Just like for any other product, the consumption of energy, raw materials and all other resources, and also the emission of solid, liquid and gaseous waste determine the sustainability of man-made fibres, but we should certainly not forget the in-use phase, in which substantial environmental savings can be made, as well as the disposal or recycling phase.



Improving the sustainability of man-made fibres is the guiding principle to improve ecological, economical and social performance. The study which measures these elements is called a Life Cycle Analysis (LCA). This study might also include further industrial operations down the pipeline and consumer operations, until final disposal or recycling. MMF are as such very diverse in their properties and performance, going through a wide range of processes, before being used in an enormous range of technical and textile

applications. This makes it very difficult to track the complete LCA, which is called cradle-to-cradle. This is the reason why many product-LCA's go from cradle to factory gate only.

Typical process steps or life cycle stages are; Raw materials, Fibre production, Fabric Production, Dyeing, Printing and Finishing, Conversion to the End Product, Transportation, Product Use and Maintenance, Recycling, Incineration or Disposal.

Measuring the sustainability performance can be made at production location or plant level. The result of this evaluation indicates the potential for product and process improvement, with the ability to focus efforts on the portion of the product lifecycle likely to produce the greatest result. Consequently, Man-made Fibre producers are continuously active on all aspects of improving the LCA and sustainability of their product. Not only existing products are further improved, but research activities are now also focused on new products environmentally outperforming the existing ones.

### **Man-Made Fibres (MMF)**

Fibres are classified in 2 groups; natural fibres and man-made fibres (MMF).

Natural fibres are fibres made by nature. Typical examples are cotton and wool, which are mainly used in textile clothing.

Man-made fibres (MMF) are fibres made by man. MMF can be organic or inorganic. Organic MMF can be made from natural materials like wood, or are made from synthetic polymers.

Viscose is a typical example and an important MMF, which is made from wood pulp, a cellulose material. Other MMF are petroleum based synthetic fibres such as polyamide, polyester, acrylic, aramids, etc.

MMF are used daily, and our daily life would look quite different without MMF. MMF are not only used in all kind of textiles and apparel, but also in a wide range of technical applications. Transport or mobility (road, air) would be quite different and primitive if no MMF were available.

The level of sustainability is not automatically defined by the term “natural” or “man-made”. To come to the product in use, the production or converting processes may negatively or positively influence the environmental footprint. Also the in-use phase must be considered. Some MMF help save energy in the in-use phase, which can only be realised by the proper application of the MMF; e.g. in composites.

MMF is continuously making efforts to further improve the sustainability of its products, by being active and improving all aspects governing sustainability.

### **Renewable Raw material**

Most of the man-made fibres (MMF) are made out of synthetic polymers where the feedstock is oil-based.

However, some MMF are also based on renewable resources. Viscose, Lyocell and Modal are typical and important MMF which are based on wood – the renewable resource. Cellulose is



the world's most important biopolymer by far. About half of the global biomass consists of cellulose, being an amazing unique biopolymer. Wood is converted into pulp, and pulp into fibres.

The pulp and fibre industry is part of the natural carbon cycle. Cellulose is created during plant photosynthesis; carbon dioxide and water are converted into organic matter. The process is powered by sunlight, and the exhaust product is oxygen. Cellulose is nature's most important construction material – natural global production is about 40 billion tons per year.

Unless cotton, cellulosic man-made fibres do not compete with food production. Only 0.2 % of wood felled globally are used for the manufacture of cellulosic man-made fibres. Furthermore, wood used for this purpose comes from sustainably managed plantations or marginal productivity areas that are unsuitable for food crops due to soil conditions, anyway.

Fuelled by the discussions on sustainability, a small but growing proportion of man-made fibres production is based on innovative raw material sources such as corn or vegetable oil. Typical examples are PLA fibres, and the use of bio-propanediol (PDO) out of corn, as a substitute for the oil-based PDO, for the polymerization of PTT polyester.

### **Non-renewable Raw Material**

Most of the man-made fibres (MMF), in product types and volume, are made out of synthetic polymers; the feedstock of which is oil-based. In the first instance, this non-renewable resource is in view of sustainability not the preferred resource compared to (rapidly) renewable sources. But this has to be considered in the context of other resources like land use and water use, needed for the production of natural fibres.



On top of that, only minor volumes of the oil resources are used for man-made fibres. Oil-based feedstock used in European production of man-made fibres amounts to an estimated 0.06% of world oil production. At a global level, MMF consume about 0.8% of the crude oil production.

Actually, still some 90 % of the petroleum produced is directly used for heating and transport. It is clear that saving on oil, has to be focused on renewable alternatives for transport and heating, where huge savings can be realised.

And without man-made fibres there would be not enough land available, if they were completely substituted by natural fibres like cotton and wool. Substitution of man-made fibres by natural fibres, will not bring a huge saving on crude oil production and use, but will go at the expense of arable land and at the expense of water. Both are essential for people daily life and will be needed for the growing population and should primarily not be used for textiles.

### **Polymer Waste as Raw Material**



Waste is to be avoided at anytime, whether it is a waste of money or a waste of resources, but it is sometimes unavoidable despite all efforts made.

Man-made Fibres (MMF) is committed to reducing the environmental impact of its operation, by reducing the use of resources and to reuse as much as possible polymer waste of whatever source, if technically and economically viable.

Polymer waste is more and more frequently used to spin man-made fibres. We have to consider Process Waste or factory waste which comes from the polymerisation process and the spinning process, and we have to consider polymer waste being Post-consumer Waste. Process waste is often sold, recycled into polymer chips and finally into short fibre. A typical example of a non-fibre, post-consumer waste recycling are the PET plastic bottles which are collected and recycled into polyester short fibre.

## **Production Processes**

### **Responsible care**

Long before the focus on sustainability, MMF was already committed to the global Responsible Care Initiative. The aim of the Responsible Care Program is to achieve ongoing improvement in protection of the environment, plant safety and in safeguarding the health of consumers and employees -independent of legal requirements.

The contribution of MMF to the Responsible Care Program has been tremendous from the point of view of saving on raw materials, energy and water, reduction of waste and reduction of emissions, for over 20 years. And last but not least it has repeatedly resulted in new products and improved processes, and rapidly excluding ideas that did not deliver a product meeting responsible care targets or sustainability requirements.



### **Management systems**

Sustained success can only be met if adequate management systems regarding quality and environment management are applied. At all operations these management systems are in place. Typical systems are ISO 9000 and 14000 series (14040, 14044), EMAS (Eco management and Audit system), etc.

These management systems do not only control but also guide ongoing improvements in safety, the work environment and protection of the natural environment. Application of these management systems minimises the probability and the consequences of accidents of whatever nature, reduces the impact of the operations, processes and products on the environment, prevents pollution, and optimises the use of natural resources.

### **Certification**

Not only the production processes are certified according the implemented management systems, in many cases the products are certified as well. A typical example is the Oeko-Tex certificate.

## **Process Waste**

MMF are committed to reducing environmental impact by reducing its use of natural resources.

Any production process is only long term economically sustainable if no or only minor process waste volumes have to be taken into account. Any process waste is costing a lot of money and should be avoided. Just think about the costly raw materials, be it renewable or not. Production sites have longstanding clear targets to further reduce process waste. Reduction of waste is an important aspect of the Responsible Care programme in which MMF participate.

However, some waste is unavoidable. As said, recovery, recycling and reuse of this waste is saving on resources and saving on money. Process or factory waste can be sold and recycled into other polymer products, but several MMF producers are now recycling their own process waste. A typical example is practiced in the polyamide carpet production where up to 70% of material originating from process waste and 30% from virgin polymer is used to make carpet yarn.



## **Process Emissions to the Air**

Emission to the air, be it from the polymer production and/or the spinning process, is strictly controlled by European and national legislation, and laid down in the environmental permit. Depending on the permit, online and regular emission-to-air measurements have to be made and reported to the authorities.

The polymerisation process is described by the Best Available Techniques (BAT), which are compiled in a BREF (BAT-Reference) document, which is in turn part of the

European IPPC-regulation (European Integrated Pollution Prevention and Control). These BREF documents are state of the art regarding emission prevention and control, resulting in European man-made fibre production facilities being amongst the cleanest in the world.

The discussion of climate change has made greenhouse gas emissions the primary focus of sustainability assessments. Where MMF producers generate their own heat and electricity, it is likely (depending on the volume) that they fall under the European Emission Trading System, which restricts the CO<sub>2</sub> emission on a yearly basis. Also because of economical reasons, MMF has set severe targets to reduce energy consumption and consequently CO<sub>2</sub> emission.

## Process Emissions to Water

Water is used for cooling of the processes and in some cases as part of the chemical process.

In the polymerisation and spinning processes, the majority of the water used is required for cooling. After only a moderate temperature increase, this water is returned to the river in an unpolluted condition.



The water used within the production process, industrial waste water, is purified in special, biological waste water treatment plants.

Emission to water, just like emission to air, is strictly controlled by European and national legislation, and laid down in the environmental permit. Depending on the permit, online and regular emission-to-air measurements have to be made and reported to the authorities.

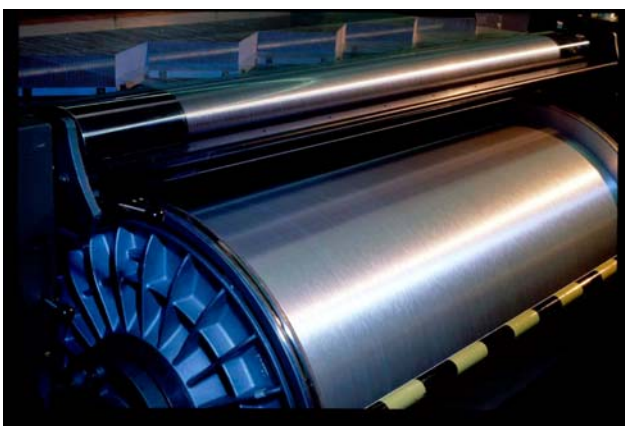
The polymerisation process is described by the Best Available Techniques (BAT), which are compiled in a BREF (BAT-Reference) document, which is in its turn part of the European IPPC-regulation (European Integrated Pollution Prevention and Control). These BREF documents are top of the world regarding emission prevention and control, resulting in the European man-made fibre production being the cleanest production location in the world.

The effect of man-made fibres on water, be it pollution by pesticides, or irrigation effects, or whatever, is non-existing.

## Process Emission to Land

Process emission to land is strictly regulated by national and European legislation and is not permitted. In case of a calamity, despite, the legislation in place imposes an immediate cleaning up of the spill.

Consequently, the man-made fibre production process does not directly result in any contamination or other deterioration of land. This is not always the case with natural fibres, where land is needed to grow the crops and where pesticides or irrigation are needed to bring about an acceptable yield.



## Product to Customer and Consumer

The product of the man-made fibre producer is a fibre or a multifilament yarn, which is basic material for development to a (technical) textile construction. This

product, just like the natural fibre, is sold to a next step in the textile supply chain, and can be weaving, dyeing, printing and finishing, and conversion to the end product. These operations are carried out on industrial installations and operations which have to meet the legislation in place. Sustainability is also a key priority for these operations, as these so-called textile after treatment processes have not always been the most environmental friendly. Dramatic improvements have been made in dyeing and water contamination. But also the man-made fibre producer has contributed to this by supplying fibres for many applications, eg. for carpets which are dyed during the fibre production process, eliminating the need for water and energy-intensive dyeing at a later stage.

Transportation can be an issue between the different steps in the supply chain, and energy use can be substantial, depending on the production location and markets. Man-made fibre producers do have systems in place to improve logistics, to reduce distribution costs and to save on energy and CO2 emissions, as well as systems to reduce the volume of packaging material and to make environmental friendly choices regarding the packaging material of choice.

## Product Use

The fibre production phase is important in view of sustainability, but in many cases the product-use phase is an even more important consideration. Is the product consuming a lot of energy during use, or is the product saving energy?



Just to mention a couple of examples out of the many applications of man-made fibres:

- The greatest application of fibres is in textiles and several studies on the energy use during a garment lifecycle have shown that consumer use (laundrying, ironing) was the predominant factor accounting for a multiple of the lifecycle energy compared to all stages of manufacturing. In general man-made fibres can be laundered at low temperatures, with large energy savings.
- Man-made fibres reinforcement of composites allows substantial weight savings in transportation like aircrafts and cars. We are just at the beginning and further penetration of composites in aircrafts and cars will be key to dramatic energy saving. Aramid fibres are applied in car tyres reducing rolling resistance, resulting in fuel saving during a tyre life time.

Man-made fibres developments do not only focus on the sustainability of the production processes, but also the sustainability of the product-use phase is considered as it may have a serious impact on the sustainability of the complete product lifecycle.

## Post-Consumer Waste

Fibre waste, which is solid, is no threat to human health unlike toxic pollutants; but the large volume of solid waste in general, generated by human activities poses significant environmental problems. Although the recent emphasis has been on recycling and other schemes to divert solid waste from disposal, a majority of solid waste still ends up in landfills or is incinerated.



When non-renewable raw materials are used in a product, the key to improved sustainability is in many cases recycling. Of course, provided, that collection and recycling systems are efficient and do not consume more non-renewable energy than is gained from the recycled product. This balance can only be determined by careful analysis. This analysis is usually valid only for the geographical area analyzed. What is sustainable for one region should not be the case for any region, due to the systems available at that time, in that geographic area.

A typical example of post-consumer waste recycling is the polyester drink bottle recycling. Carbonated soft drinks bottles and water bottles made from PET are collected and delivered to recycling plants, where they are cleaned, chopped into 'flakes', which are spun into man-made fibres, mainly staple fibre. Carbon emissions associated with making polyester fibre from used PET bottles are only a fraction of the emissions associated with fibre made from virgin chemicals.

By now, over 70% of polyester staple produced in the European Union is made from recycled materials, mainly PET bottles but also factory waste. Most of the output goes into fillings and nonwovens, but some European companies are also producing fibres suitable for some spinning uses. Fine fibres for spinning are still predominantly based on virgin raw materials.

Another example of recycled post consumer waste is carpet recycling. In Europe carpet recycling is just ready to start, while in the US a carpet recycling network has been established for quite some years through the C.A.R.E. programme.

Any textile waste which cannot be recycled can be efficiently incinerated with electricity and heat recovery, because of the high calorific value of man-made fibres.

### **Product use Emission**

The man-made fibre is, apart from raw material production, the first step in the textile supply chain, followed by weaving, dyeing, printing and finishing, conversion to the end product, the use phase, the post-consumer waste phase, followed by recycling, incineration or landfill. All these steps may result in emission to air, water or land. If industrial installations and operations are concerned, these will have to meet the legislation in place.

Sustainability is also a key priority for these operations. Dramatic improvements have been made in dyeing and water contamination. But also the man-made fibre producer has contributed to this by supplying fibres which are dyed during the fibre production process, eliminating the need for water and energy-intensive dyeing at a later stage.

In many cases the product-use phase is even more important than the production phase regarding sustainability. Is the product consuming a lot of energy during use, or is the product saving energy? The greatest application of fibres is in textiles and several studies on the energy use during a garment lifecycle have shown that consumer use (laundering, ironing) was the predominant factor accounting for a multiple of the lifecycle energy compared to all stages of manufacturing. In general man-made fibres can be laundered at low temperatures, with large energy savings.

Man-made fibres reinforcement of composites allows dramatic weight savings in transportation like aircrafts and cars resulting in huge energy savings. Fibres are applied in car tires reducing rolling resistance, resulting in fuel saving during a tire life time.

And finally there is the post-consumer waste phase. When non-renewable raw materials are used into a product, the key to improved sustainability is in many cases recycling. Of course, provided, that collection and recycling systems are efficient and do not consume more non-renewable energy than is gained from the recycled product. A typical example of post-consumer waste recycling is the polyester drink bottle recycling. Carbon emissions associated with making polyester fibre from used PET bottles are substantially less than the emissions associated with fibre made from virgin chemicals. By now, over 70% of polyester staple produced in the European Union is made from recycled materials, mainly PET bottles but also factory waste.

Any textile waste which cannot be recycled can be efficiently incinerated with electricity and heat recovery, because of the high calorific value of man-made fibres.

## **Energy**

Because of competitiveness, saving on energy has always been an issue. Fuelled by the global discussion on green house gas emission and the sky high energy prices, all European man-made fibre producers have invested heavily to reduce their energy consumption. The European industry in general, has reduced the energy use by 30% compared to 1990, which is more than anyone else in the world. The man-made fibre industry has contributed to that by yearly energy savings of 2 to 5% in average.

In Europe, energy is in general supplied by combined heat power installations, generating both electricity and steam for the production process at the same time. These installations are generally fired with environmentally compatible natural gas which contains virtually no pollutants.

Where economically feasible, waste is burned. The waste heat from the combustion processes is incorporated into the steam network and used for production. By doing this, substantial quantities of natural gas can be saved. Flue gas purification system is located downstream of the incineration facility, guaranteeing that the strict exhaust air regulations are met.

As the result of the European Emission Trading System it is expected that the availability of low environmental impact energy that comes from renewable sources will increase. The man-made fibre industry will certainly take the opportunity to switch to these “green” energy sources.

## **Water Use**

Worldwide, water resources are limited and precious. With a growing population the situation is expected to get tighter and tighter. Fortunately, and contrary to natural fibres, the amount of water needed for the production of man-made fibres (MMF) is limited. The amount of water needed for cotton crop cultivation, by far the most important natural fibre, is much higher and doubtful in ecological terms.

Without man-made fibres (MMF), or if only natural fibres would be used, there would be not sufficient water resources for humankind. The water for the MMF production is consumed by almost all processes for use either as cooling water or process water. Depending on the local situation different supply sources are used.

Despite the fact that the use of water per kg of MMF is limited, water saving programmes are put in place and progress and results are reported on a regular basis as defined in the environmental permit.

Not only water saving programs are put in place, but also targets for water emission reduction are formulated and executed. These emission or water discharge reduction actions to the water treatment installations are also part of efforts to be made in view of the environmental permits.

## **Land Use**

It is obvious that for man-made (MMF) fibres very little land is needed, compared to natural fibres of vegetable or animal origin. For MMF from synthetic polymers almost no land is needed, while these fibres represented in 2008 60% of the total global fibre production. For cellulosic man-made fibres, like viscose, only about 3 to 4% of the land used for natural fibre production is needed. 27% of the land is needed for cotton, representing about one third of global fibre production, and 69% of the land is needed for wool representing only 2% of the global fibre production. Needless to say that synthetic man-made fibres cannot be abandoned in favour of natural fibres. There is just not enough land available, for an exclusive switch to wool or cotton, without leading to global famine or ecological catastrophes.

For viscose fibres, having beech and eucalyptus wood as raw material, land unsuitable for food production can be used, in combination with 50 to 400% higher fibre yield. The concept of sustainability is rooted in forestry. It entails forests being managed in a way that enables perpetual functionality, not only in terms of raw material supply, but as the habitat of flora and fauna, protection against erosion and landslides, and as a recreational retreat and as an aquifer.

Today, arable farm land is and will be in the future, more than ever before vital to sustain food production for the world population, and not for production of fibres to clothe the world population.

## **Research & Development**

The European man-made fibres industry is the world's second largest man-made fibres producer, spending € 1 billion in innovation and investing €1.2 billion over the last five years. Europe is the global leader in polymer modified fibres (flame-retardant, bioactive ...) and leader in clean production techniques.

Research and Development is focused on improved sustainability of manufacturing processes and fibre products. An improved sustainability performance is a prerequisite for spending of R&D money, further development and investment.

Burgeoning "green chemistry" initiatives, where bio-based materials are being studied as renewable sources of both fuels and chemicals that are currently produced from petroleum, are looked at as well.

## **Social Responsibility**

Without people, we could not develop, produce, or sell any products. Social factors are increasingly included in sustainability assessments. The argument for inclusion is that necessary workforces cannot be sustained over time without basic rights and fair treatment. The problem from an assessment standpoint is not that social factors are unimportant, but that they are often difficult to measure and quantify.

Factors that are often included in assessments include: Worker and community health and safety regulations, working conditions, worker rights and "Living Wage", forced labour, child labour and guarantees of non-discrimination, training opportunities, employee input and freedom to innovate. Everybody comes to work in a healthy condition, and should go home in a healthy condition.